I. GENERAL REMARKS ON INVESTIGATION

By Atsuyuki Mizuno and Junsuke Chujo

Introduction

An investigation of deep sea manganese nodule deposits by the Geological Survey of Japan has been carried out since 1969 as a project of 'fundamental study on deep sea mineral resources prospecting'. Preliminarily investigations have been carried out up to 1973 on the deposits in the southern part of the Western Pacific. Through these activities we have clarified the concentration of ores in deep sea red clay to the northwest of the Marshall Islands and the Magellan Seamounts. Some of the results were published in the Cruise Report of Geological Survey of Japan No. 1 (Takeda, ed., 1974).

Since 1974, the launching of the Geological Survey Vessel 'Hakurei-Maru' (Geological Survey of Japan, 1974) enabled us to do a more intensive and systematic survey of manganese deposits.

Using this vessel, which is equipped with various modern instruments, a total of 100 days of survey cruises in the fiscal year 1974 were spent in the investigation of the manganese deposits of the Eastern Central Pacific Basin and east of the Okinawa Islands. The present report is concerned with the investigation results in the former area.

The surveyed area was chosen as an example of an area of nickel and copper rich manganese nodules. The present work represents the first step of a successive year plan of investigation of the whole Central Pacific Basin manganese deposits. Although some contributions hitherto published are available concerning to geology and ore deposits in the area, their detailed features have not been clarified, and we made it our first aim of investigation to clarify an outline of ore deposits in the area and their relation to topography, sedimentology and general geology, and secondly to roughly delineate a promising area for prospecting of the deposits. Thus, areal geological, geophysical and optical surveys were carried out in the area and also some geophysical works were done during the long tracks from Japan to the area via Hawaii and from the area back to Japan (Fig. I-1).

The surveyed area is located in the eastern part of Central Pacific Basin (6°–10°30′N, 164°30′–171°30′W) and is mostly represented by a deep sea basin at a depth of 5,000–5,400 m. To the north and east, it is bounded by the seamounts and guyots chain of the Christmas Ridge at a depth of 1,500–2,000 m (Fig. I-2).

According to Chase et al. (1971), the eastern part of the area is represented by nearly flat topography, but the median and western parts are characterized by rolling topography with many deep sea hills and some seamounts. Moreover in this area a striking linear arrangement of relief in a NW-SE direction is recognized as a whole (Winterer, Ewing et al., 1973). Previous reports show that surficial sediments of siliceous ooze widely cover the area and those of calcareous ooze and siliceous-calcareous ooze are developed in the central and eastern districts (Horn et al., 1972 and Frazer et al., 1972). The occurrence of manganese nodules has been reported from some localities and chemical analyses have shown rather high concentrations of Ni and Cu particularly in nodules in the western and northern districts of the present area (Horn et al., 1972 and Horn et al, 1973). Data on submarine geology are available for the eastern part of area by DSDP (Winterer, Ewing et al., 1973).

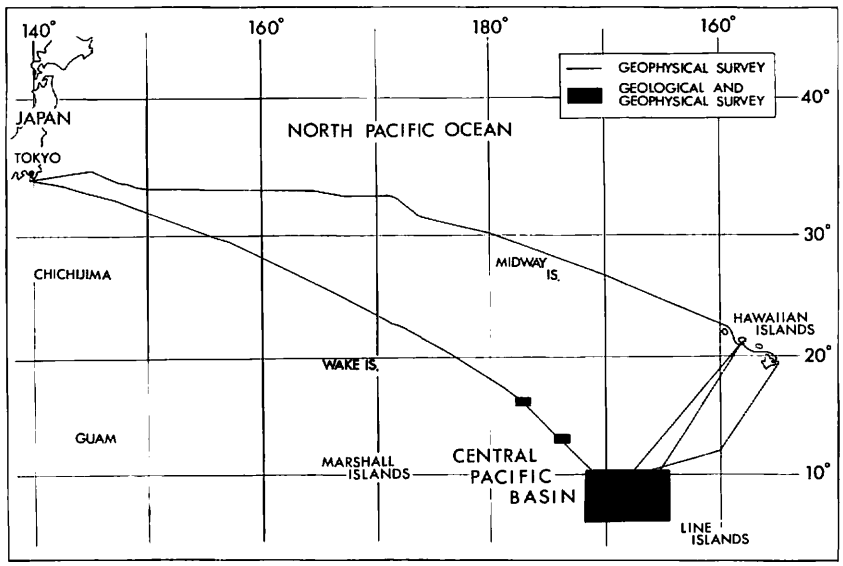

Fig. I-1 The surveyed area and tracks.

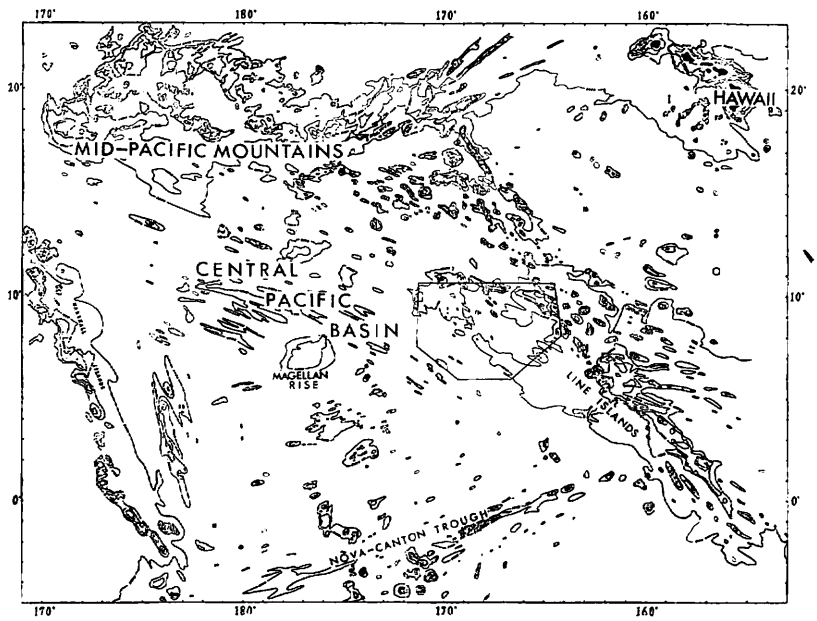

Fig. I-2 Submarine topography of the Central Pacific Basin after Winterer *in* Winterer, Ewing et al. (1973) and surveyed area shown by closed lines.

Outline of investigation

To carry out the various types of surveys, seventeen scientists were present on-board the 'Hakurei-Maru' commanded by Captain S. Toki. They came from the Geological Survey of Japan (thirteen scientists including technical assistants), the National Research Institute for Pollution and Resources (three scientists) and the Metal Mining Agency of Japan (one scientist), and the members of N.R.I.P.R. aimed to achieve their investigations on survey technique of subsea mineral resources. They are listed in Table I-1. Besides these members, six observers from the Deep Ocean Minerals Association helped them in on-board studies.

The vessel sailed from Chiba Port adjoining to Tokyo, on the 14th of August, 1974, and arrived in the surveyed area on the 3rd of September via a stay at Honolulu, Hawaii for several days. The cruise ended on return to Chiba Port on the 17th of October of the same year (Table I-2 and Appendix).

For the total distance of 12,843.7n.m. during sixty-five days, that of about 3,200n.m.

Table I-1 On-board scientific staffs.

Name	Organization	Speciality
Atsuyuki MIZUNO	G.S.J.	*Chief scientist*, geology
Junsuke CHUJO	G.S.J.	*Co-chief scientist*, geophysics
Shuji MARUYAMA	G.S.J.	Senior scientist, ore deposits
Eiichi HONZA	G.S.J.	Senior scientist, geology
Kaichi ISHIBASHI	G.S.J.	Techinical official, topography
Masato NOHARA	G.S.J.	Scientist, geology and geochemistry
Kensaku TAMAKI	G.S.J.	Scientist, geology
Masafumi ARITA	G.S.J.	Scientist, geology and sedimentology
Yasumasa KINOSHITA	G.S.J.	Scientist, geology and optical survey
Fumitoshi MURAKAMI	G.S.J.	Scientist, satellite navigation
Kazuo SAITO	G.S.J.	Technical assistant
Fuminori YAMAMOTO	G.S.J.	Technical assistant
Saburo AOKI	G.S.J.	Technical assistant
Norio YAMAKADO	N.R.I.P.R.	Senior technologist, survey technique
Takeshi USAMI	N.R.I.P.R.	Technologist, survey technique
Keiji HANDA	N.R.I.P.R.	Technologist, survey technique
Kenji SAWADA	M.M.A.J.	Scientist, geology

Table I-2 Schedule of Cruise.

Aug. 14	Lv. Chiba (14: 00)
Aug. 26	Ar. Honolulu (08: 00)
	Staying at Honolulu for water and food supplying, rest of members aboard and examination of materials on marine geology.
Aug. 31	Lv. Honolulu (14: 15)
	Marine geology surveying on the area west of the Line Islands.
Sept. 16	Ar. Hilo (08: 25)
	Staying at Hilo for rest of members aboard.
Sept. 20	Lv. Hilo (16: 05)
Sept. 21	Ar. Honolulu (09: 00)
	Fuel, water and food supplying.
Sept. 22	Lv. Honolulu
	Marine geology surveying on the area west of the Line Islands.
Oct. 5	Lv. the surveyed area.
Oct. 17	Ar. Chiba (09: 20)

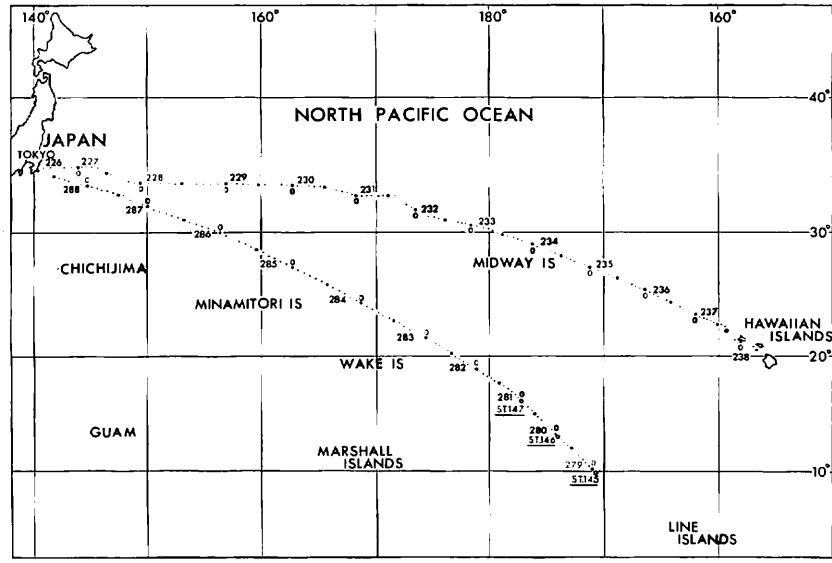

Fig. I-3 Geophysical tracks, Japan–Hawaii and surveyed area–Japan. Dates being shown by the Julian calender (226, 227 . . .), and dots indicating ship's position every two hours.

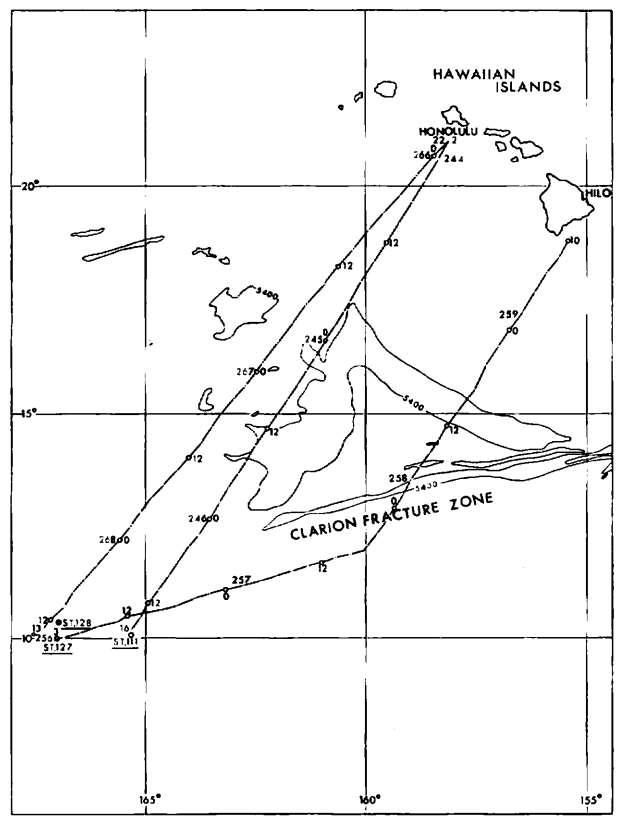

Fig. I-4 Geophysical tracks of surveyed area–Hawaii.

was spent for observation in the surveyed area by geological, geophysical and optical methods during twenty-three days and the remaining time was spent for geophysical traverses from off the Boso Peninsula to Honolulu, Honolulu to the surveyed area, the surveyed area to Hilo and the surveyed area to off Boso Peninsula (Figs. I-3, 4).

Table I-3 summarizes the survey methods of our study.

Among various methods under positioning by NNSS, special consideration was given to bottom sampling by the Okean-70 grab, continuous seismic reflection profiling by air-gun and 3.5 KHz PDR profiling. The piston coring and optical survey by deep sea television and still camera were supplementally used. Gravity and magnetism measurements were carried out over the whole surveyed area.

Fig. I-5 shows the stations and tracks observed in the surveyed area. They were rather closely spaced in the western district, and moreover a rather dense survey by various methods was made in a narrow part in the western extremity (Sts. 120–123, 136–140), where manganese nodule deposits were expected, according to our earlier survey, to have a good distribution, for the purpose of clarifying the details of their areal distribution. Stationary observations were made at 35 stations, and the results of these observations are summarized in Table I-4.

Among some of the sampling tools used, the Okean-70 grab, which was modified from the original Russian Okean-50 grab (Inoue, 1971), was used for the purpose of obtaining undisturbed samples of bottom sediments and manganese nodules and to estimate the population density of nodules. Having a bottom area of about 0.5 m^2 (0.7 m × 0.7 m) and a weight of about 350 kg, it enabled successful and effective sampling at 17 stations out of a total of 21.

With regard to cruising and positioning by NNSS, our particular attention was given

Table I-3 Observation methods.

Cruising and positioning by NNSS	
Geophysical method	
Bathymetric survey by 12 KHz PDR	—Prospecting of bottom topography
Subbottom profiling by 3.5 KHz PDR	—Prospecting of sedimentary surficial beds
Seismic profiling survey by air-gun	—Prospecting of sedimentary beds and geological structure
Magnetic survey by proton magnetometer Gravity measurement by on-board gravimeter	—Auxiliary consideration of general geological structure
Geological method	
Bottom sampling by chain-bag, cylinder and large box dredges	—Sampling of sediments, rocks and nodules at seamount area and sampling of a large amount of nodules
Bottom sampling by Okean-70 grab	—Obtaining undistrubed surficial sediments and nodules, particularly for quantitative study of population density and occurrence of nodules
Bottom sampling by piston corer with 6 m core-barrel and by gravity corer	—observation of vertical sequence and manganese nodules of surficial sedimentary columns
Optical method	
Observation by deep sea still camera Continuous observation by deep sea television	—Monitoring of nodule distribution and sedimentary feature of sea floor

to on-board examinations regarding the field status of satellite fixes and the errors of dead reckoning.

Summary of results of on-board investigation, with special reference to manganese deposits

In the surveyed area, manganese deposits include two types of manganese nodule and crust, the former being found in sediments of the deep sea basin floor and the latter cover-

Table I-4 Results of

St. No.	Sampling No.	Julian Day	Local		Position			
			Day	Time ▼ ▲	Lat (N) ▼	Long (W) ▼	Lat (N) ▲	Long (W) ▲
111	D 50	246	9.03	09: 16–09: 28	10 03 7	165 19 8	10 03 9	165 19 8
112	D 51	247	9.03	15: 14–16: 08	09 50 9	165 46 9	09 51 5	164 44 8
113	D 52	247	9.04	09: 25–09: 57	08 20 6	164 23 7	08 20 3	164 23 0
114	P 12	248	9.04	15: 16	08 09 7	164 50 0		
115	G 39	248	9.05	10: 15	08 00 0	166 56 7		
116	TV 1	249	9.05	15: 50–16: 45	08 03 0	166 54 8	08 02 8	166 53 1
117	G 40	250	9.07	09: 51	06 01 7	166 55 7		
118	C 1	251	9.07	14: 16–14: 53	06 02 7	166 57 4	06 02 1	166 57 1
119	G 41	251	9.08	09: 54	05 59 6	166 00 7		
120	TV 2	252	9.09	12: 03–13: 01	08 09 7	170 25 5	08 08 3	170 24 2
121	G 42	253	9.10	08: 32	08 10 5	170 27 4		
122	D 53°	253	9.10	11: 28–12: 06	08 09 6	170 26 7	08 09 2	170 26 4
123	C 2	254	9.10	15: 25–15: 56	08 09 4	170 25 7	08 09 4	170 25 7
124	G 43	254	9.11	09: 43	09 20 1	168 50 8		
125	D 54°	254	9.11	12: 45–13: 59	09 20 2	168 51 8	09 20 1	168 51 9
126	G 44	255	9.12	09: 56	09 30 3	167 03 5		
127	P 13°°	256	9.12	15: 27	10 00 1	167 02 8		
128	D 55	268	9.25	09: 04–09: 24	10 21 6	166 58 9	10 21 8	166 59 0
129	G 45	269	9.25	14: 51	10 00 1	167 37 0		
130	G 46	269	9.26	09: 35	09 01 3	167 50 9		
131	G 47	270	9.26	15: 48	08 52 5	167 23 0		
132	G 48	270	9.27	09: 42	07 00 1	167 49 3		
133	G 49	271	9.27	16: 36	07 16 9	168 07 3		
134	G 50	271	9.28	10: 00	07 13 2	169 34 7		
134–1	G 50–2	272	9.29	09: 40	07 10 8	169 36 8		
135	D 56°	273	9.29	15: 06–15: 59	07 33 0	170 00 8	07 32 3	170 00 5
136	G 51	273	9.30	09: 49	08 29 4	170 25 5		
137	C 3	274	9.30	14: 30–15: 00	08 10 4	170 25 2	08 10 6	170 25 2
138	P 14	274	10.01	10: 11	08 11 0	170 09 7		
139	D 57°	275	10.01	14: 22–15: 24	08 10 3	170 25 0	08 10 3	170 24 2
140	TV 3	275	10.02	09: 52	08 10 1	170 14 8		
141	D 58	276	10.03	09: 26–10: 25	08 15 7	168 50 2	08 16 1	168 50 5
142	G 52	277	10.03	14: 39	08 02 9	169 02 9		
143	G 53	277	10.04	08: 15	10 00 0	168 42 1		
144	G 54	278	10.04	14: 25	10 00 3	168 11 1		
145	G 55	278	10.05	09: 35	09 55 8	170 40 3		
146	G 56	279	10.06	09: 38	13 06 9	173 59 3		
147	P 15	280	10.07	09: 54	16 08 8	177 10 9		

D; Chain bag dredge and Cylinder dredge G; Okean 70-type grab P; Piston corer C; Deep-sea camera TV; Deep-sea television °°; Gravity corer (D = 120 mm) °; combined a big box-type dredge ▼; on bottom ▲; roll up start □;

ing sea floor rocks on seamounts and guyots lying along the eastern and northern margins. In the following, manganese deposits of the nodule type are summarized only.

Manganese nodules are only rarely found on the topographically flat sea-floor in the eastern half of the area, where a thick turbidite layer of upper Eocene-Miocene age occurs beneath surficial siliceous-calcareous sediments. Although, the nodules are extensively developed in the western half of the area, their abundance varies areally. Siliceous and siliceous-calcareous sediments and deep sea clay cover the sea floor of the area.

stationary observations.

Depth (m)	Results		
		Bottom materials	Mn-nodule
1340	□	Calcareous ooze and Basalt	
2900	□	Calcareous ooze and Basalt	
1660	□	Calcareous ooze and Basalt	
5000	△	Siliceous-Calcareous ooze (≒DSDP SITE 165)	
5190	△	Siliceous ooze/Siliceous-Calcareous ooze	
5150	△	Siliceous ooze (?), Worm trace abundant	
4950	△	Siliceous-Calcareous ooze	
4930	△	Siliceous-Calcareous ooze, Worm trace abundant	
5760		Fail	
5803	●	Mn-nodule abundant	
5450	●	Siliceous ooze, Siliceous clay	19 kg/m²
5635	●	Siliceous clay	9 kg
5470		Fail	
5200	●	Siliceous clay	8.5 kg/m²
5170	●	Siliceous ooze	11 kg
5010	●	Siliceous-Calcareous clay	15 kg/m²
5230		Dark brown clay	
2880	□	Calcareous ooze, Mn-crust	
5259	●	Siliceous ooze	12 kg/m²
5270	●	Siliceous ooze	0.1 kg
5228	●	Siliceous clay/Siliceous ooze	trace
5164	●	Siliceous-Calcareous ooze	14 kg/m²
5277	●	Siliceous ooze/Siliceous clay	2 kg/m²
5570		Fail	
5524	●	Siliceous clay/Siliceous ooze	trace
5554	●		2 kg
5338	●	Siliceous ooze/Siliceous clay	trace
5450	●	Covering ratio of Mn-nodule 70–75%	
5480	●	Siliceous ooze/Clay	trace
5530	●		43 kg
5500		Fail	
4800	●		9 kg
5150	●	Siliceous clay	1 kg/m²
5152	●	Siliceous-Calcareous ooze	26 kg/m²
5300	●	Siliceous clay/Clay	7 kg/m²
4930	●	Siliceous-Calcareous ooze/Calcareous clay	1 kg/m²
5610	●	Siliceous clay/Clay	5 kg/m²
5356	●	Clay	trace

Manganese crust ●; Manganese nodule △; Manganese nodule and crust absence

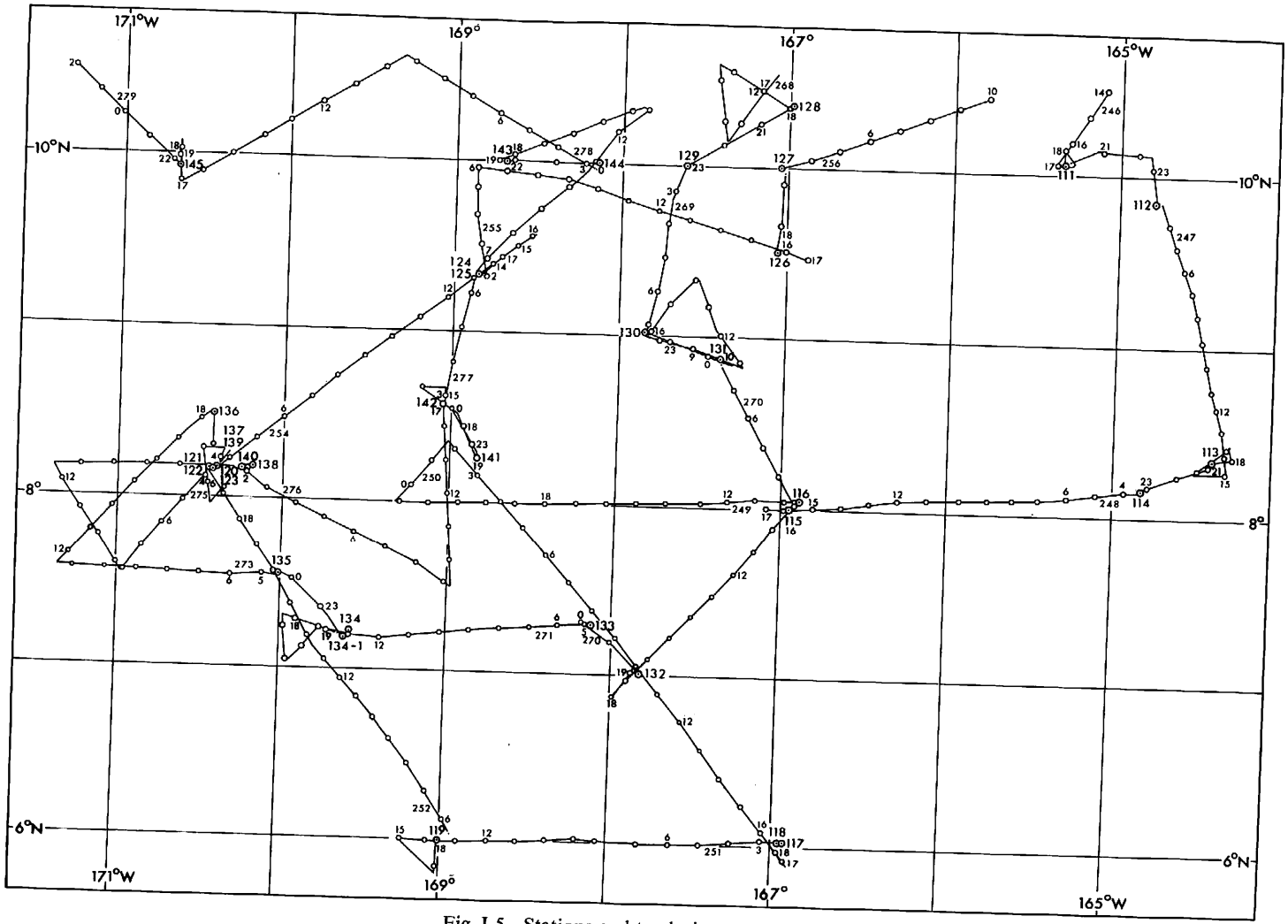

Fig. I-5 Stations and tracks in surveyed area.

In the hilly areas, nodules are poorly developed, and even in some areas of high concentration, their horizontal extent is limited to very narrow areas, particularly that of intra-hilly basins. They are most abundant on the rather flat deep sea basin at about 5,000 m depth which lies just south of the northern seamounts chain and is considered to be the most promising field in the surveyed area.

The nodules are dark bluish black or black in color, measuring an average of 4–2 and/or 2–1 cm in diameter, and occur on the surface of the sea bottom, their lower half being buried. They are variously shaped, i.e., spheroidal, subspheroidal, polylobate, botryoidal, discoidal, subangular or slab-like.

The population density of the nodules varies horizontally in the distribution area, ranging from less than 1 kg/m^2 to a maximum of 26 kg/m^2. The density is areally irregular and abruptly changes even over short distance. The areas with the highest density seems to be rather widely developed in the northern area mentioned before.

Generally the higher density tends to be restricted to the deposits in siliceous-calcareous sedimentary facies of bottom materials, and also tends to be related to the thickness of the transparent layer shown by 3.5 KHz PDR. This relationship is very pronounced. A population density of more than about 5 kg/m^2 is related to the transparent layer with a thickness of less than about 20 m, and moreover a population density of more than about 20 kg/m^2 tends to be restricted to the 10–20 m thick transparent layer. Slab-like nodules tend to be associated with the transparent layer where it is less than about 10 m thick.

The relationship between the population density of nodules and the thickness of the transparent layer obtained by 3.5 KHz PDR may therefore be significant for nodule genesis (in a quantitative sense) and prospecting.

Analytical results on obtained nodule samples show concentrations of Mn 14–24%, Ni 0.6–1.3% (mostly less than 1%) and Cu 0.3–1.1 (mostly less than 0.5%). In the promising areas the Ni content ranges from 0.5 to 1.19%.

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